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Application Number : 200104056-7

Applicant(s) : DATA STORAGE INSTITUTE

Title of Invention : METHOD AND APPARATUS FOR CUTTING A SUBSTRATE USING LASER IRRADIATION

Sharmaine Wu Shee Mei
Assistant Registrar
for REGISTRAR OF PATENTS
SINGAPORE

PATENTS FORM 1

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PATENTS ACT
(CHAPTER 221)
PATENTS RULES

Rule 19

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200104056-7

The Registrar of Patents
Registry of Patents

REQUEST FOR THE GRANT OF A PATENT

THE GRANT OF A PATENT IS REQUESTED BY THE UNDERSIGNED ON THE BASIS OF THE PRESENT APPLICATION

I. Title of Invention	**METHOD AND APPARATUS FOR CUTTING A SUBSTRATE USING LASER IRRADIATION**	
II. Applicant(s) *(See note 2)*	(a) Name	**DATA STORAGE INSTITUTE**
	Body Description/ Residency	A company limited by guarantee
	Street Name & Number	DSI Building, 5 Engineering Drive 1 (off Kent Ridge Crescent, NUS)
	City	
	State	
	Country	Singapore 117608
	(b) Name	
	Body Description/ Residency	
	Street Name & Number	
	City	
	State	
	Country	
	(c) Name	
	Body Description/ Residency	
	Street Name & Number	
	City	
	State	
	Country	

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III. Declaration of Priority *(see note 3)*	Country/Country Designated		File No.	
	Filing Date			
	Country/Country Designated		File No.	
	Filing Date			
	Country/Country Designated		File No.	
	Filing Date			
IV. Inventors *(see note 4)* (a) the applicant(s) is/are the sole/joint inventor(s)	☐ Yes		☒ No	
(b) A statement on Patents Form 8 is/will be furnished.	☒ Yes		☐ No	
V. Name of Agent (if any) *(See note 5)*	**ALLEN & GLEDHILL**			
VI. Address for Service *(See note 6)*	Block/Hse No.	36	Level No.	18
	Unit No./PO Box	01	Postal Code	068877
	Street Name	**ROBINSON ROAD**		
	Building Name	**CITY HOUSE**		
VII. Claiming an earlier filing date under Section 20(3), 26(6) or 47(4). *(See note 7)*	Application No.			
	Filing Date			
	[Please tick in the relevant space provided]: ( ) Proceeding under rule 27(1)(a). Date on which the earlier application was amended = _____ or ( ) Proceeding under rule 27(1)(b).			

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VIII. Invention has been displayed at an International Exhibition *(See note 8)*	☐ **Yes** ☒ **No**
IX. Section 114 requirements *(See note 9)*	The invention relates to and/or used a micro-organism deposited for the purposes of disclosure in accordance with Section 114 with a depository authority under the Budapest Treaty ☐ **Yes** ☒ **No**
X. Check List (To be filled in by applicant or agent)	A. The application contains the following number of sheet(s):-

1. Request	4	Sheets
2. Description	9	Sheets
3. Claim(s)	3	Sheets
4. Drawing(s)	5	Sheets
5. Abstract	1	Sheets

B. The application as filed is accompanied by:-

1. Priority document		
2. Translation of priority document		
3. Statement of Inventorship & right to grant		
4. International Exhibition certificate		

XI. Signature(s) *(See note 10)*	Applicant (a)	
	Date	**6 July 2001**
	Applicant (b)	
	Date	
	Applicant (c)	
	Date	

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NOTES:

1. This form when completed, should be brought or sent to the Registry of Patents together with the prescribed fee and 3 copies of the description of the invention, and of any drawings.

2. Enter the name and address of each applicant in the spaces provided at paragraph II. Names of individuals should be indicated in full and the surname or family name should be underlined. The names of all partners in a firm must be given in full. The place of residence of each individual should also be furnished in the space provided. Bodies corporate should be designated by their corporate name and country of incorporation and, where appropriate, the state of incorporation within that country should be entered where provided. Where more than 3 applicants are to be named, the names and address of the fourth and any further applicants should be given on a separate sheet attached to this form together with the signature of each of these further applicants.

3. The declaration of priority at paragraph III should state the date of the previous filing, the country in which it was made, and indicate the file number, if available. Where the application relied upon in an International Application or a regional patent application e.g. European patent application, one of the countries designated in that application [being one falling under the Patents (Convention Countries) Order] should be identified and the name of that country should be entered in the space provided.

4. Where the applicant or applicants is/are the sole inventor or the joint inventors, paragraph IV should be completed by marking the "YES" Box in the declaration (a) and the "NO" Box in the alternative statement (b). Where this is not the case, the "NO" Box in declaration (a) should be marked and a statement will be required to be filed on Patents Form 8.

5. If the applicant has appointed an agent to act on his behalf, the agent's name should be indicated in the spaces available at paragraph V.

6. An address for service in Singapore to which all documents may be sent must be stated at paragraph VI. It is recommended that a telephone number be provided if an agent is not appointed.

7. When an application is made by virtue of section 20(3), 26(6) or 47(4), the appropriate section should be identified at paragraph VII and the number of the earlier application or any patent granted thereon identified. Applicants proceeding under section 26(6) should identify which provision in rule 27 they are proceeding under. If the applicants are proceeding under rule 27(1)(a), they should also indicate the date on which the earlier application was amended.

8. Where the applicant wishes an earlier disclosure of the invention by him at an International Exhibition to be disregarded in accordance with section 14(4)(c), then the "YES" Box at paragraph VIII should be marked. Otherwise the "NO" Box should be marked.

9. Where in disclosing the invention the application refers to one or more micro-organisms deposited with a depository authority under the Budapest Treaty, then the "YES" Box at paragraph IX should be marked. Otherwise, the "NO" Box should be marked.

10. Attention is drawn to rules 90 and 105 of the Patent Rules. Where there are more than 3 applicants, see also Note 2 above.

11. Applicants resident in Singapore are reminded that if the Registry of Patents considers that an application contains information the publication of which might be prejudicial to the defence of Singapore or the safety of the public, it may prohibit or restrict its publication or communication. Any person resident in Singapore and wishing to apply for patent protection in other countries must first obtain permission from the Singapore Registry of Patents unless they have already applied for a patent for the same invention in Singapore. In the latter case, no application should be made overseas until at least 2 months after the application has been filed in Singapore.

For Official Use

Application Filing Date	:	/	/
Request received on	:	/	/
Fee received on	:	/	/
Amount	:		
* Cash/Cheque/Money Order No	:		

** Delete whichever is inapplicable.*

Method and apparatus for cutting a substrate using laser irradiation.

This invention relates to a method and apparatus for cutting a substrate using laser irradiation. In particular, it relates to such a method and apparatus for use with a substrate bearing integrated circuit components. The invention has particular application in the singulation of integrated circuit components using laser irradiation.

Silicon wafers or integrated circuit (IC) units are typically made up of a number of individual layers. These layers may comprise a printed circuit board (PCB) package upon which are provided some or all of the following; metal circuitry, dielectrics, wafer dies, bonding wires and moulding compound materials. Typically, a number of individual IC units will be formed on one package, which will be marked so as to define the boundaries of the individual IC units. It is therefore necessary to singulate the package so as to separate each individual IC unit.

A known singulation technique is that of mechanical sawing. US Patent 6140708 to Lee et al, entitled "Chip Scale Package And Method For Manufacture Thereof", discloses a manufacturing process in which the individual units are singulated from an encapsulated package using a diamond saw. This prior technique has many drawbacks. The saw must be manufactured to exacting standards of homogeneity and flatness. Water is also required during the sawing process to clean the sawing debris and to dissipate the heat generated. Another disadvantage is that the

high degree of wear requires frequent saw replacement, which leads to high equipment costs. Furthermore, the minimum cut width of the saw imposes limitations on the density of IC unit fabrication. In addition, the mechanical sawing process can lead to cracks, particularly in relation to thinner IC units. In addition, metal substrates have recently gained in popularity due to their low cost. Typically, a substrate will have a copper plate base coated with a layer of nickel. However, metal substrates generate metal debris which can lead to even greater problems. The metal debris tends to stick to the saw blade, leading to damage to both the IC units and the saw blade itself.

Another technique for the singulation of IC units is that of laser singulation. WO 01/10177 (XSIL Technology Limited) discloses a method and apparatus for singulation of IC units using a laser. The laser energy is scanned across the IC package using either rotating or laterally moveable mirrors. This method also has drawbacks. The cutting speeds attained by using this technique are quoted as 4.2 mm/sec and 8.3 mm/sec. Furthermore, the thickness of package suitable for cutting using this technique is limited by the depth of focus of the laser beam. This technique is therefore not suitable for many industrial applications.

There is therefore a requirement for an improved method and apparatus avoiding the above disadvantages. In particular, there is a requirement for a method and apparatus for cutting a substrate using

laser irradiation that avoids the problems of diamond-wheel saw dicing (e.g. cost of saw blades, frequent wear, large minimum cut width, cracking, need for water to remove debris and dissipate heat) while providing reasonable cutting speeds and being suitable for use with thicker substrates.

It is an object of the present invention to fulfil the above requirements.

According to the above object, the invention comprises a method of cutting a substrate comprising the steps of:

a) focussing laser energy onto a point on the substrate so as to provide a laser focus point on the substrate;

b) effecting relative lateral movement between the said laser focus point and the said substrate so that the said point follows a first path on the said substrate, a first layer of the said substrate being removed along the said first path so as to reveal a second layer of the said substrate;

c) refocussing the laser energy onto the said second layer, so that the laser focus point is located on the said second layer; and

d) effecting relative lateral movement between the said laser focus point and the said substrate so that the said point again follows substantially the said first path on the said substrate, whereby a second layer of the said substrate is removed along the said first path.

Preferably, steps c) and d) are repeated, a further layer of the substrate being removed with each repetition, until all layers of the substrate have been removed along the said first path.

Advantageously, the laser energy used has a wavelength in the ultra-violet to visible range. Further advantageously, the laser energy used has a wavelength greater than 500 nm, preferably 532 nm.

Preferably, a fluid flow is directed towards the cut region. Particularly preferably, the said fluid is air.

According to one embodiment, the substrate is provided with a plurality of Integrated Circuit (IC) units formed thereon, the method being used to singulate the various units.

According to another aspect, the invention provides apparatus for carrying out the above method.

For a better understanding of the present invention and to show more clearly how it may be carried into effect reference will now be made, by way of example, to the accompanying drawings which show schematically various embodiments of the present invention. The figures may not be to scale.

Figure 1A shows an embodiment of an apparatus according to the invention;

Figure 1B is an enlarged partial view showing the invention used to cut a package;

Figure 2A shows a first type of uncut package, bearing a number of IC units, suitable for cutting using the invention;

Figure 2B shows an IC unit separated from the package of Figure 2A;

Figure 3A shows a second type of uncut package, bearing IC units, suitable for cutting using the invention;

Figure 3B shows an IC unit separated from the package of Figure 3A;

Figure 4 is a graph showing the relationship between laser output power and cutting speed;

Figure 5 is a microscope photo showing the cut edge of an IC package;

Figure 6 is a photo showing a sample IC package with IC units cut using the present invention.

According to Figures 1A and 1B, a laser cutting apparatus according to one embodiment of the invention comprises an Nd:YAG laser (10) which generates a laser beam (12), a beam expander (15), a reflecting mirror (20), a Z-stage (60) and a lens (30) affixed thereto. The laser beam (12) passes through the beam expander (15) and is reflected by mirror (20) through lens (30) onto a package (40) which is carried by an X-Y stage (50). The package (40) has a number of IC units fabricated thereupon and may be of the type shown in Figure 2A or 3A. A coaxial air blow system having an air blow nozzle (80) is

provided to blow air onto the cut region. Relative movement between the package (40) and the laser beam (12) is provided by suitably controlling the movement of the X-Y stage (50). This movement may be controlled by a suitably programmed computer (70). The computer (70) also controls the laser (10) and the Z-stage (60). Suitable software is provided so that appropriate processing parameters can be selected, including laser parameters, X-Y stage parameters and Z-stage parameters.

At the start of the cutting process, the compressed air supply is initiated so that air is blown out of the nozzle (80) onto the surface of the package (40). The laser beam (12) is focussed onto the uppermost surface of the package. Under the control of the computer (70), the X-Y stage causes the package (40) to move, so that the laser beam moves along a cutting track (47). Alternatively, any suitable means for effecting suitable relative lateral movement may be employed. A first layer (42) of the package is ablated by the laser beam (12) and removed, exposing the second layer (44) and forming a first kerf (147). Once the laser beam has scanned to the end of the package, the beam is refocussed onto the now-revealed second layer (44). This is achieved by moving the lens (30) using the Z-stage (60), although any means for effecting suitable relative vertical movement may be employed, as may any other suitable refocussing means. In this way, real-time adjustment of laser optics is provided. Following the refocussing step, the beam passes back along the cutting track. During this pass, the second layer (44) is

removed along the cutting path, forming a second kerf (247). The first and second kerfs (147, 247) together therefore separate the package along the path (47). In this example, two passes are sufficient to cut through the entire depth of the package (40), but for thicker packages more passes may be required. Figure 1B shows a substrate having undergone a first pass and in the process of completing a second pass in the direction of the arrow shown (from right to left in Figure 1B).

The scanning direction may be along the X or Y axes or a combination of the two. Each laser scan will therefore remove one layer of the material from the package. Following this scan, the focal lens is stepped down using the Z-stage to refocus the laser beam onto the next layer. The focal point is therefore always kept on the working layer of the IC package. The stepping distance of the lens can be calculated by dividing the IC package thickness by the number of scans.

An alternative method of operation is to move the laser focus point to its initial position after the first pass is completed. The laser may be turned off (e.g. by using a shutter) during this return step. In this way, the package has an opportunity to cool down during the return step.

During the cutting process, compressed air supplied by the nozzle (80) is used to remove the debris created by the ablation of the

package material and to dissipate heat. The direction of the air flow is preferably the same as the laser incident direction. This debris-removal feature allows the cutting groove to remain clear of debris and ready for the next scanning step.

The above process is repeated in the X and Y directions so as to singulate the package (40) into separate IC units.

The cutting speed can be expressed according to the following equation:

$$V_s \propto k(v, p, \lambda, \theta, f) \times \frac{P}{(W \times H)}$$

where

V_s is the cutting speed;

P is the laser power used in the process;

W is the cutting width;

H is the thickness of the package; and

k is a proportionality factor dependent on the laser scanning speed (v), the laser wavelength (λ), the divergence of the laser beam (θ), the air blow pressure (p) and the focussing of the laser beam (f).

It can be seen that the cutting speed V_s is proportional to the laser power P and inversely proportional to the cutting width (W) and package thickness (H). The value of the proportionality factor k varies depending on the setup of the apparatus. The laser wavelength

(λ) in particular can be selected depending on the material to be cut. In the case of copper, for example, the desired wavelength is in the ultraviolet band, which is more efficient when cutting metal. Furthermore, pulsed laser irradiation is used as this provides high peak power while generating less heat. The air blow pressure (p) has a threshold value at which the debris is completely removed. The focussing factor (f) determines the intensity of the incident radiation, as different beam sizes will be required for different cutting widths.

Figure 5 shows the smooth cut edge obtained using the present invention. Figure 6 shows a plurality of IC units separated from an IC package by using the invention. Using the invention, the speed of singulation and the quality of the cut edges are comparable to those obtained by mechanical saw singulation.

It is preferable to use high-speed multiple scans rather than low-speed single scans as the shorter beam-dwell-time results in less heat build-up. This feature, and the various other heat-dissipation features described above, allow heat accumulation to be avoided, so preventing damage due to overheating.

CLAIMS

1) A method of cutting a substrate comprising the steps of:

a) focussing laser energy onto a point on the substrate so as to provide a laser focus point on the substrate;

b) effecting relative lateral movement between the said laser focus point and the said substrate so that the said point follows a first path on the said substrate, a first layer of the said substrate being removed along the said first path so as to reveal a second layer of the said substrate;

c) refocussing the laser energy onto the said second layer, so that the laser focus point is located on the said second layer; and

d) effecting relative lateral movement between the said laser focus point and the said substrate so that the said point again follows substantially the said first path on the said substrate, whereby a second layer of the said substrate is removed along the said first path.

2) A method according to claim 1 wherein steps c) and d) are repeated, a further layer of the substrate being removed with each repetition, until all layers of the substrate have been removed along the said first path.

3) A method according to any previous claim wherein the laser energy used has a wavelength in the ultra-violet to visible range.

4) A method according to claim 3 wherein the laser energy used has a wavelength greater than 500 nm.

5) A method according to claim 4 wherein the laser energy used has a wavelength of 532nm.

6) A method according to any previous claim wherein a fluid flow is directed towards the cut region.

7) A method according to claim 6 wherein the said fluid is air.

8) A method according to any previous claim wherein the substrate is provided with a plurality of Integrated Circuit (IC) units formed thereupon, the method being used to singulate the various units.

9) Apparatus for cutting a substrate comprising:

a) a laser beam source;

b) focussing means for focussing the said laser beam onto a particular point on the substrate so as to provide a laser focus point on the substrate;

c) relative motion generating means for effecting relative lateral movement between the said laser focus point and the said substrate so that the said point follows a first path on the said substrate, a first layer of the said substrate being removed along the said first path so as to reveal a second layer of the said substrate;

refocussing means being provided to refocus the laser beam onto the said second layer, relative motion between the laser focus point and the substrate again being effected along the said first path so as to remove a second layer of the said substrate along the said path.

10) Apparatus according to claim 9 wherein the focussing means comprises a lens arrangement; the refocussing means comprising means for effecting relative vertical movement between the lens arrangement and the substrate.

11) Apparatus according to any previous claim wherein the laser beam wavelength is in the ultra-violet to visible range.

12) Apparatus according to claim 11 wherein the laser beam wavelength is greater than 500nm.

13) Apparatus according to claim 12 wherein the laser beam wavelength is 532 nm.

14) Apparatus according to any of claims 9 - 13 wherein means are provided to direct a fluid flow towards the cut region.

15) Apparatus according to claim 14 wherein the said fluid is air.

16) Apparatus according to any of claims 9 - 15 wherein the substrate is provided with a plurality of Integrated Circuit (IC) units formed thereupon, the apparatus being used to singulate the various units.

17) A method substantially as herein described and illustrated in the accompanying drawings.

18) Apparatus substantially as herein described and illustrated in the accompanying drawings.

ABSTRACT

Method and apparatus for cutting a substrate using laser irradiation.

The invention relates to a method and apparatus for cutting a substrate using laser irradiation. A laser beam is scanned over a substrate. The beam ablates a first layer of the substrate. The beam is then refocussed onto the newly revealed second layer and a further pass is performed. The process is repeated until complete separation occurs. The method and apparatus are particularly suitable for singulation of IC packages.

(Figure 1A)

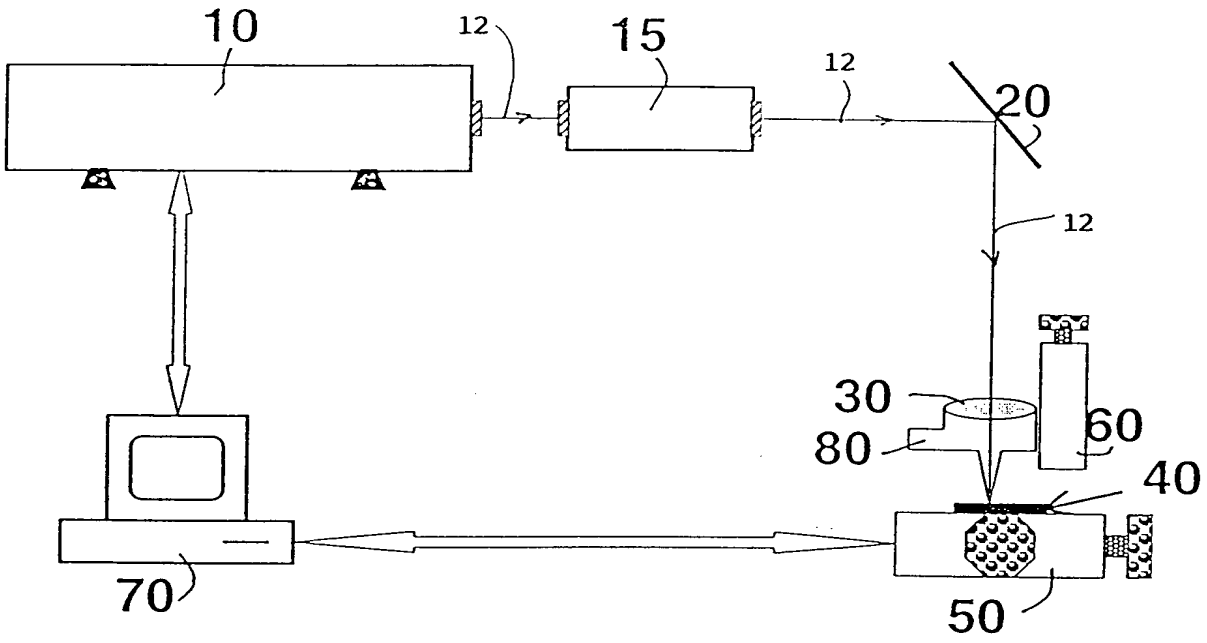

FIG. 1A

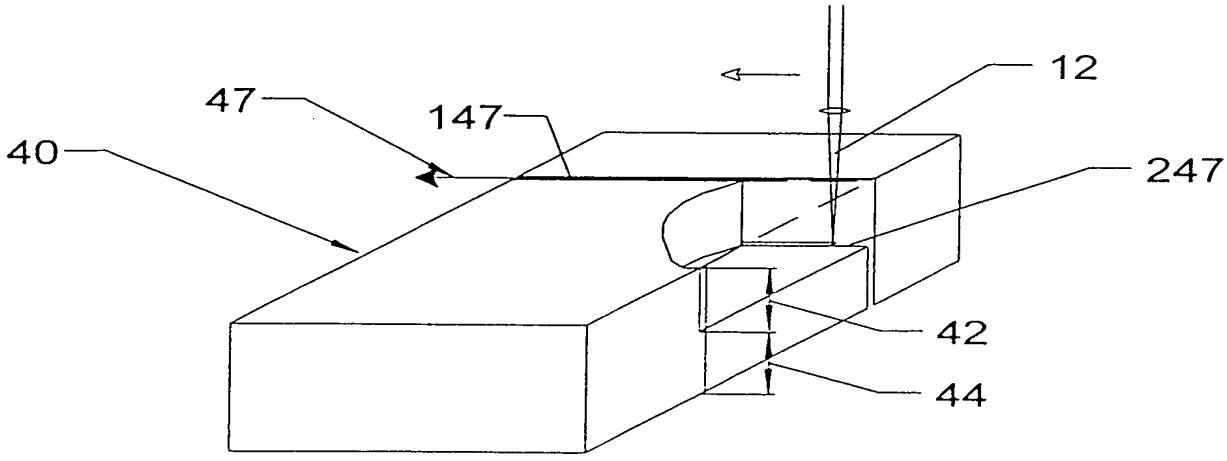

Fig. 1B

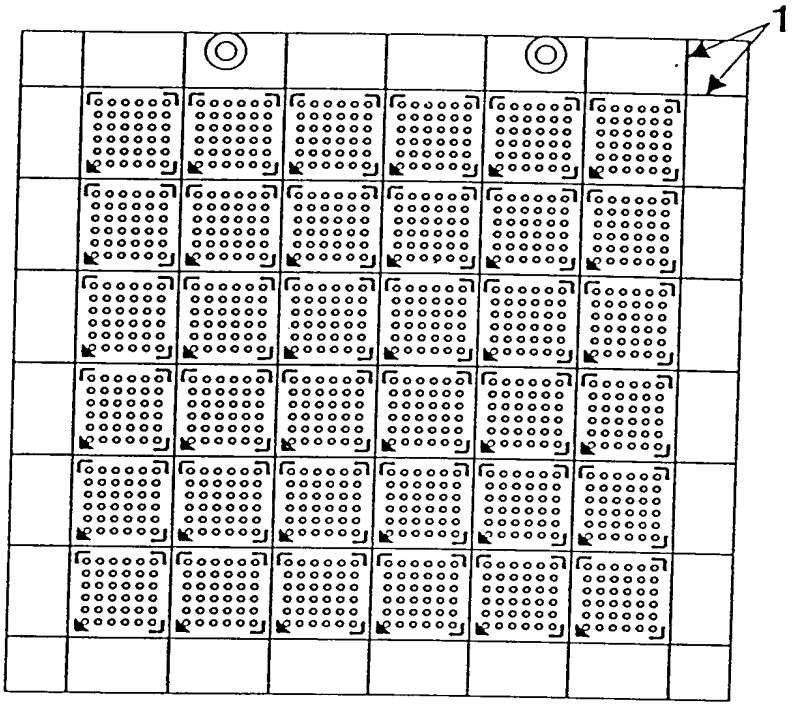

FIG. 2A

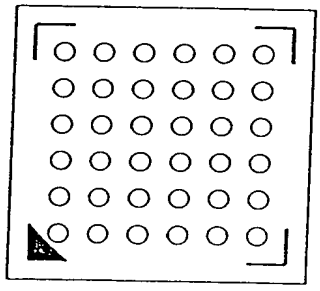

FIG. 2B

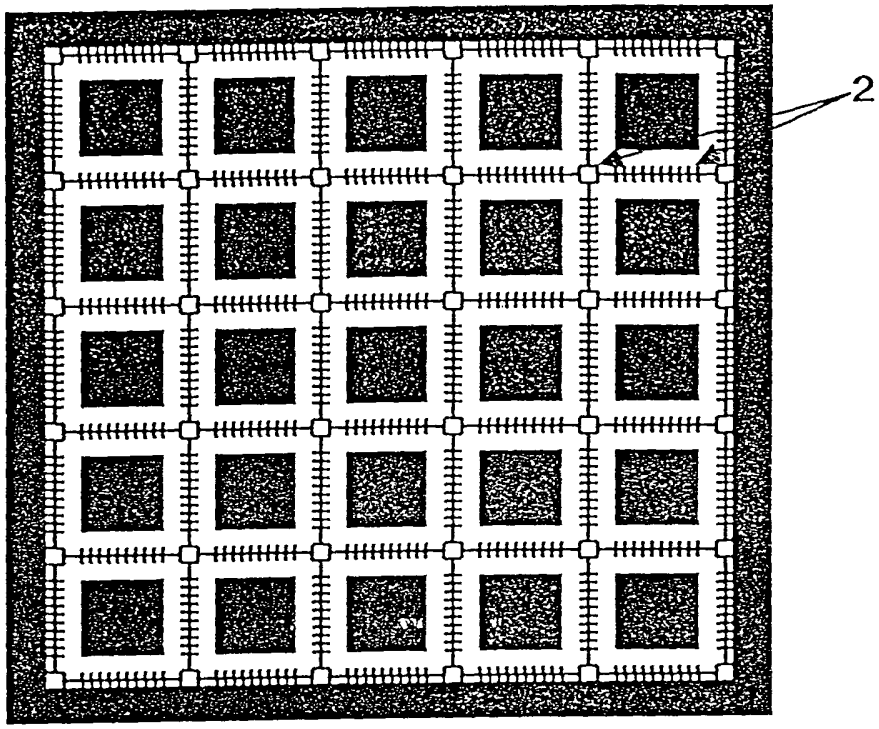

FIG. 3A

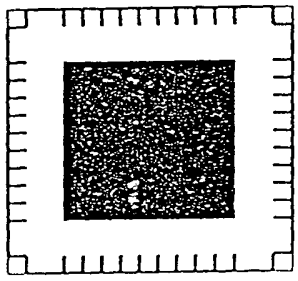

FIG. 3B

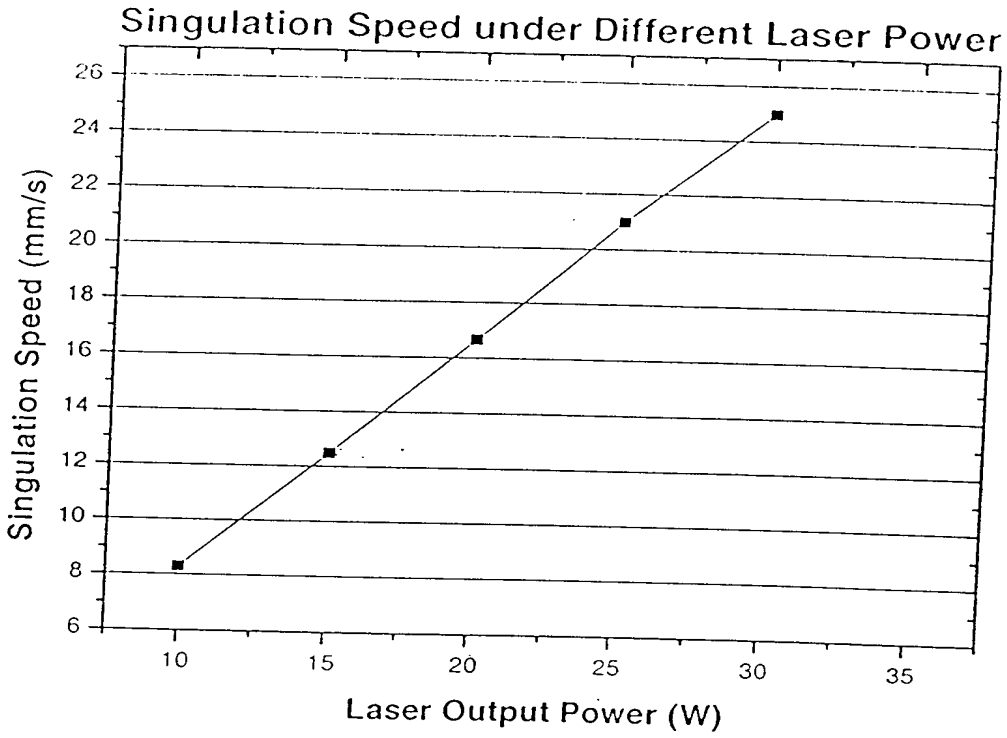
Singulation Speed under Different Laser Power
Singulation Speed (mm/s)
26
24
22
20
18
16
14
12
10
8
6
10
15
20
25
30
35
Laser Output Power (W)

FIG. 4

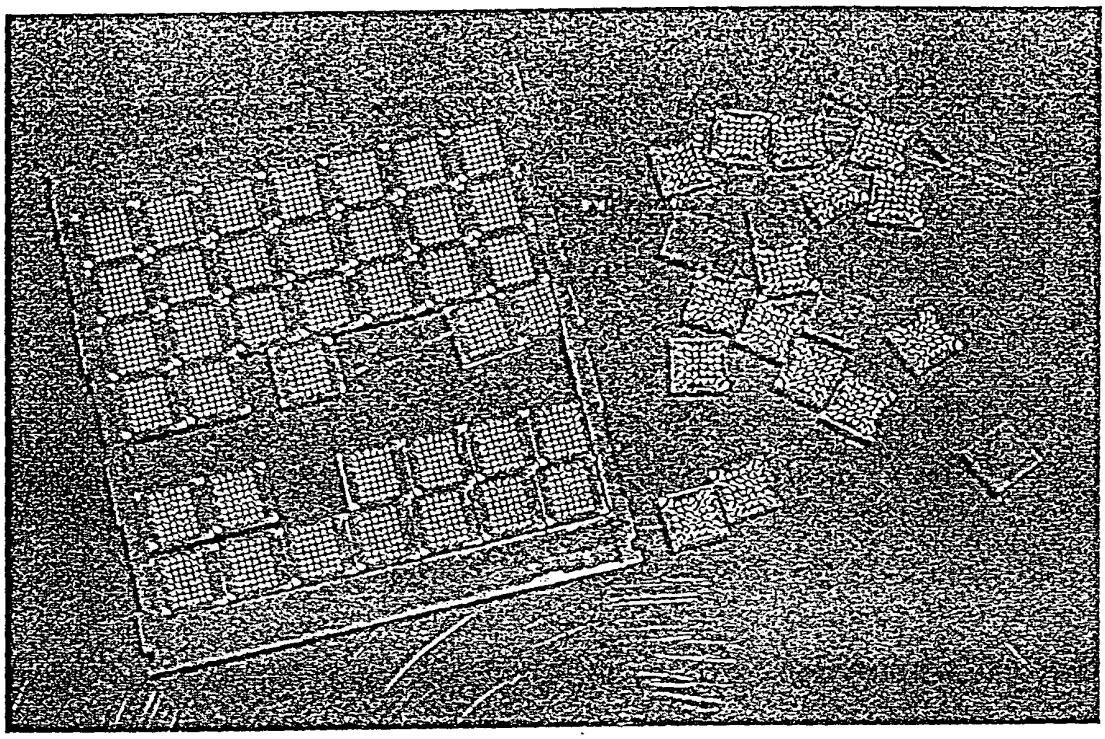

FIG. 6

FIG. 5